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THE PURIFICATION OF PUBLIC WATER SUPPLIES.

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Professor Hyde in a recent report upon a water supply for Sacramento, assumed that the question of quantity was of much more importance than the question of quality in the first instance. It is taken for granted that, no matter what the quality may be in the raw state, as long as the quantity is sufficient to meet all future wants, the eventual quality can be guaranteed by the adoption of purification methods.

Now this assumption as a basis for a report on a probable water supply has only been made possible of late years. Custom was at one time to insist upon an analysis of any probable water supply, and on the strength of that analysis to either accept or disregard it. This custom, however, is now subject to certain qualifications.

We know that no community can grow beyond its available pure water supply. Pure water is an absolute necessity to a community. If we have an island containing no potable water, no man can exist on that island. If there is only water for one man, then one man only can exist, and so on. No matter what latent wealth that island may contain, without potable water or the means of delivering potable water, that wealth is useless.

So in Canada where we have great areas of land wealthy almost beyond measure in productive fertility, the realization of such wealth is subject to the supply of potable water. There are town sites on the prairie which can never become practically more than town sites; there are villages which cannot become towns; towns which cannot become cities, and cities which cannot grow beyond a limited population, because of the fixed quantity of available pure water.

At the present day the amount of available pure water is much greater than it was, say, ten years ago; because we now know of efficient means by which impurities either inorganic or organic can be removed from water, and so water which at one time would, on analysis, have remained condemned may now be classed as potable. This is the meaning of Professor Hyde's assumption. We can now go straight for quantity leaving the question of quality to be taken care of as an afterthought. This does not mean that quality has no bearing on the choice in the first instance. It only means, as it did at Sacramento, that although a pure ground water supply existed in territory to the south east of the city estimated at 20 million gallons per day, that Hyde advised the city to pump from a polluted river source with an unlimited supply which would meet the probable growth of the city. In fact, the original pure water supply would have limited the city growth, whereas the abundant originally impure supply satisfied an unlimited city growth. A few years ago the growth of Sacramento was limited, by means of our newer knowledge of treating impure waters, its growth is now unlimited.

As to the modern requirements of a pure water supply, allow me to quote from Hyde's report above referred to:—

(a) The supply must be abundant and unfailing.
(b) The water must be free from pathogenic germs.
(c) The water must be free from those allied organic forms which may not as yet be recognized as accompanying disease, but which may, nevertheless, not be conducive to health.
(d) The water must not be discolored.
(e) The water must at all times be free from taste and odors.
(f) The water must be uniformly clear and free from turbidity, both that which may be produced by suspended mineral matters and that which may be due to suspended organic impurities.

To the above may also be added that water should not contain more than 15 degrees of total hardness and 5 of permanent.

It is very difficult and rare to obtain water which meets all of the above requirements. Settled large basins of water present the nearest approach to the ideal. Almost all rivers, whether pathogenically polluted or otherwise, are apt to present turbidity at times. Spring waters, though free from turbidity and generally pathogenically pure, are apt to contain the salts peculiar to the strata in which they are found, and are hence generally excessively hard, and at times even unfit for domestic use unless artificially softened.

It will be impossible for me in the limited time at my disposal to treat of methods for removal of all forms of impurities from water. I intend, therefore, to confine my remarks more particularly to methods and principles applied chiefly for the removal of pathogenity.

Filtration has been and remains the most generally accepted method of purifying water. We know that water in passing through the surface layers of the earth very quickly loses all trace of original organic impurities, and the only impurities it may contain must be new ones picked up by contact with the earth. It is, therefore, apparent that if we can artificially reproduce and improve upon the best conditions which exist in earth surface layers, we shall produce a method of water purification. That method has been evolved in the system called "Slow Sand Filtration." There is nothing of a mysterious nature, nothing of a complicated chemical character, takes place with slow sand filtration. The whole process simply amounts to a method of straining. There are certain engineering features connected with the regulation of the water as applied; but beyond these, the filter is simply a bed of sand of a given area and thickness, capable of allowing a given quantity of water to percolate from the surface to the underdrains. The filters are subject to constant saturation, and are worked with a depth of water covering the whole surface sufficient to overcome the friction produced by the sand. The quantity of water which can be dealt with daily varies from 1¾ million gallons to 6¾ per acre, depending upon the quality and character of the raw water and the size of the sand grains used.

We have said that the whole process is simply one of straining. Thus, it differs almost entirely from the sewage filter, the object of which is not only to strain or hold back, but also to bring about certain chemical changes in the filtrate. Sand filtration does its most important work on and in the surface layer to a depth of about one quarter of an inch. The sand pores are not sufficiently fine in themselves to effectually keep back bacteria. The first few days' working of a sand filter is practically useless as a means of removal of pathogenic impurities; but as a scum of matter, deposited from the water, forms a carpet over the whole surface, bacterial removal efficiency increases to almost 100%. This scum formation is the peculiar feature which gives to slow sand filtration its unassailable position as the best mechanical method of removing pathogenity from the water. Like all human contrivances, however, it has its drawbacks. Chief of these is, that the surface scum continues to thicken until it becomes almost impervious and must be removed. Covered in sand filters average in cost on this continent from fifty to sixty thousand dollars an acre and to this must be added cost of pumps, pipe connections and all the other necessary appurtenances. The cost of operation ranges from two dollars per million gallons at Mt. Vernon, N.Y., to almost six dollars at Lawrence, Mass.

Slow sand filtration has been termed the English system of treating water. It has been adopted largely in Europe and latterly in the United States, and is now being installed in connection with the water supply of the City of Toronto.

It may here be said that the introduction of water filtration has universally been followed by a marked reduction in the so called water borne diseases, especially in the typhoid rate. At Hamburg the typhoid death rate averaged 47 per 100,000 for the five years previous to the installation of filters, and only 7 for the five years following. At Zurich, before the introduction of filters the typhoid death rate was 69 and after filtration 10. At Lawrence, Mass., the figures were 113 and 25 under similar circumstances. At the present time over 30,000,000 people throughout the world are being supplied with filtered water, more than one third of this number being in Great Britain. London, Liverpool, Birmingham, Leeds, Sheffield, Dublin, Leicester, Newcastle and Edinburgh are among some of the large cities in Great Britain using sand filters. In Europe we have Hamburg, Berlin, Breslau, Chennitz, Madenburg, Altona, St. Petersburg, Warsaw and Antwerp, where such filters have been in successful operation for many years. There are also similar plants at Calcutta, Bombay, Agra, Shanghai, Hong Kong, Tokyo, Yokohama, Osako and other cities. In the United States there are slow sand filters at Philadelphia, Pittsburg, Washington, Albany and many other places. In Canada there is one plant at Victoria, B. C. The typhoid death rate for Canada is 35 per 100,000, for European countries 16.

Slow sand filtration is an effective method of purifying water. It is costly both in construction and operating expenses. It requires exact and careful management; this applies to all methods of water purification. A bacteriological laboratory should be run in connection with the plant. It is in every sense more suited to wealthy and large communities than to small.

There is another form of filtration more distinctly American called "mechanical" or "rapid filtration." This system at once appeals to the layman because of the small space it occupies. Whereas slow sand filters will treat on the average 2½ million gallons per day, rapid filters average 120 million gallons per day. The sand used is coarse grained, and efficiency in purification depends not so much upon the filter itself, as upon preliminary sedimentation accompanied by the use of a coagulant. The filters are generally installed in units equal to about a hundreth part of an acre. High purification efficiencies are obtained by technical care in regard to proper working and the scientific application of the coagulant. Generally speaking the bacterial removal efficiency is below that of slow sand filters. The makers, and there are many, do not as a rule guarantee a removal of more than 97% of total bacteria, whereas 99%, and over, removals are looked for with slow sand filters. The temptation to use mechanical filters in this country is very great, as they can be installed easily in a building in connection with the pump plant and so guarded from severe frost.

With reference to the use of a coagulant I will quote from a report of the "Joint Special Committee to examine and report relative to the pollution of Water Supply, and the best method of filtration", City Document No. 15 of the city of Providence, R. I., as follows:—

"If the diameter of matter floating about in water is much less than that of the interstices between the grains of sand composing the filter bed, such matter, except as much as is caught upon the sharp edges of the quartz, will go right through the filter with the water.

"Now, if a substance could be introduced, drop by drop, into the water before it comes to the filter bed, which would have the effect of curdling the matter together, so that every one hundred or so of the smaller particles were made to join together and become one large particle, much as vapor or steam is condensed into drops, it would follow that they would be caught and held from going through the filter. This is accomplished by adding alumina (alum) to the water as it flows to the filter.

"The amount required is from almost none at all to about three quarters of a grain, according to the state of the water, say, an average of from one quarter to one half grain per gallon in the ordinary condition of the Pawtucket River water.

"The action is the same as when coffee is cleaned by means of the white of egg. No white of the egg goes to the drinker of the coffee—it is all drained off with the grounds; and as no alum goes to the drinker of the water, it unites with the impurities in the water and settles in feathery flakes of insoluble hydrate on the top of the filter, and is washed out with its accumulation of impurities when the filter is cleaned.

"The analysis of the purified water shows no trace of the alumina used, while the analysis of the wash water shows that the alumina is all washed out with other impurities. This feathery bed of precipitate flakes produced by the alum forms a filtering media of insoluble mineral matter which is well nigh perfect in its character. Bacteria are like the very fine particles of clay of some water, so small as to pass the sand or quartz, but they are caught by the feathery precipitate of alumina hydrate, much as the bacteria contained in air are prevented from entering a phial closed with sterilized wool."

So we see that, first, as in the case of the slow sand filter, so with the mechanical, bacterial removal efficiency does not so much depend upon the filtering material itself as upon an artificial surface or blanket being formed.

One of the most successful installations of mechanical filtration is that at Harrisburg, Pa. The average bacterial removal is above 99%, being 99.62% for the year 1908.

Now the assertion may be made that these methods of filtering water are not perfect. Efficiencies are given of something over 99%, but what about the remaining bacteria, the percentage number of which must depend upon the original number to start with. For instance there were days last year when the Harrisburg water presented as many as 85,250 bacteria colonies per c.c. Now a 99 per cent. removal would yet leave over 800 bacteria per c.c. in the water.

The answer to the above assertion is contained in the one word "sterilization." If a water is so impure from a pathogenic point of view that it requires to be filtered and it is necessary to guarantee it at all times then "disinfection", or "sterilization" as it is sometimes called, must form a final adjunct to any filtration process. This principle has been recognized for some time in Europe as illustrated by the number of ozone treatment plants which have been added to filtration plants. In many of the European rivers the bacterial counts run so high, that it is impossible to obtain by any method of filtration results which come anyway near the recognized standard for filtered water, viz, not more than 100 bacteria per c.c.

The principle is also being recognized in this continent. Nashville, Minneapolis, Quincy, New Jersey and many other towns, even including Harrisburg, have adopted methods of disinfecting the water, while in Canada we have several temporary plants installed in Toronto, Montreal, Pembroke and several in Western Canada.

Disinfection by ozone has not as yet found much favor in this continent, the disinfectant chiefly used being chlorine obtained from chloride of lime. With the Siemens, Halske & De. Fries system, efficient disinfecting results can be obtained with ozone. The process, however, of forcing contact between the ozone and the water is expensive, and even in cases as at St. Maur, Paris, costs more than the production of the gas. The difficulty arises owing to the fact that ozone is practically an insoluble gas in water, hence the difficulty of obtaining contact with every drop of water. In the case of chlorine in the form of hypochlorite we have a salt which is soluble in water, and which if properly mixed reaches every particle of water. The well known disinfecting action of chlorine depends upon its power of combining with the hydrogen of water and liberating the oxygen; thus $CL_2+H_2O=2\ HCL+O$.

This atom of oxygen is said to be nascent at the time of liberation and in this form acts as a most powerful disinfectant. The bleaching power of chloride of lime is due to the same reaction. As long as the lime is kept dry it has no bleaching action, but when in contact with moisture the reaction at once takes place.

The high disinfecting efficiencies obtained by mixing chlorine with water has, of late, brought it into great favor as a temporary expedient in cases of typhoid outbreaks due to impure water. The plant necessary for treatment can be fixed up practically in one day. The cost is a mere bagatelle, and the operating expenses run about 50 cents per 1,000,000 gallons of water treated.

The plant need not consist of any more elaborate detail than two or three 60 gallon casks with a small tank supplied with a ball cock to maintain a constant head fitted with a regulating tap at the orifice.

Hypochlorite is most economically and readily obtained from chloride of lime, the lime containing on the average about 33 per cent. of available chlorine. It is usual to mix in the barrels a one per cent. solution of the lime with water, viz., at the rate of 1 lb. of chloride of lime to 100 lbs. or 10 gallons of water. The lime settles out as calcium hydrate, and the liquid is led to the orifice tank from which it is dosed into the water supply in the necessary proportion.

The proportions of available chlorine to the amount of water requiring disinfection varies with the character of the water. Turbid water and water containing considerable amounts of vegetable matter require much more chlorine than waters which are practically free from these conditions. Ontario Lake water as normally represented by the quality at the intake is efficiently disinfected by the addition of .33 parts of available chlorine to 1,000,000 parts of water. Some waters require not more than .15, while others will practically eat up chlorine before it has any chance to act as a germicide. The reason for this variation is the affinity of organic matter to oxygen. No hard and fast rule can, therefore, be laid down for its application. Where a water may vary in condition. relative to turbidity and organic content, so the amount of chlorine must also be varied. The application is not dependent upon any hard and fast rule, but must be based upon a scientific knowledge of degrees of cause and effect.

A water which can be most efficiently treated with any disinfectant which relies upon nascent oxygen, should present constant conditions. If these constant conditions are not peculiar to a raw water, then they should be assured by some preliminary treatment before the disinfectant is applied. The preliminary treatment may take the form of sedimentation, slow sand filtration, mechanical filtration, or a combination of sedimentation and filtration, depending upon local conditions. This practically means that in the majority of cases disinfection is not likely to supersede the accepted general methods of purifying water, but that it will merely form an adjunct or final process, by which any water can be absolutely guaranteed as free from disease germs.

The introduction of disinfecting processes will probably in the future tend to a more favorable acceptance of rapid filter methods rather than slow methods. The main reason as we have seen, for a preference for slow sand filtration as against mechanical filtration, has existed in the higher efficiency of the former as a germ remover. Our newer knowledge that water of a constant character, as turned out by a mechanical filter, can be sterilized at a small cost, has caused many of the advocates of slow sand filtration to reconsider their former conclusions.

The question has been asked, whether the addition of hypochlorite deleteriously affects water for purposes of domestic use. The answer is, that the small amounts of chlorine required, do not in any way affect the water. Where it might be necessary to use large amounts of chlorine, the water must of a necessity receive preliminary treatment to allow of only reasonable amounts being used. The author is of opinion that our present knowledge of the subject limits the permissible amount of chlorine to about .50 parts in 1,000,000.

At the above rate of application it would require with chloride of lime containing 33 per cent. of available chlorine, as follows:

1.5 lbs. of chloride of lime to 1,000,000 lbs. of water.
=1.5 lbs. of chloride of lime to 100,000 gals. of water.
=15 lbs. of chloride of lime to 1,000,000 gals. of water.

In order to make a 1 per cent. solution sufficient for 1,000,000 gallons of water, it would require the 15 lbs. of chloride of lime to be mixed with 1500 lbs. of water, or 15 lbs. of lime to 150 gallons of water.

There is no doubt that disinfecting processes of water treatment have come to stay, just what form their exact relation will take up relative to older methods being yet somewhat undecided. However, I have as far as possible endeavored to lay before you the present situation relative to purification of water as far as the removal of pathogenity is concerned. Time will not allow of entering into the hundred and one other impurities which it may at times be necessary to treat. We have algae growths, vegetable iron growths, such as ferrigmous slime, spongidae, all kinds of complications caused by inorganic matters in solution, all of which are interesting and capable of remedy.

Sufficient is it, if I have shown you that waters, which at one time would have remained condemned as possible sources of water supply, may now be brought into general use.

MERCURY ARC RECTIFIERS.

H. A. COOCH, B.A.Sc.

The mercury arc rectifier was first introduced to meet the demand for some device for rectifying from alternating to direct current, economically, efficiently, and without occupying too much space in the power station. It is the case in a great many stations and substations at present that only alternating current machines are in use. As a result, it would necessitate a great outlay to install direct current machinery to supply d.c. needs. In such cases it is apparent that this arc rectifier is to play an important part in the betterment of local substation economics.

The first to realize the rectifying properties and possibilities of mercury was Mr. Peter Cooper-Hewitt, of the Cooper-Hewitt Mercury Arc Lamp Co., now absorbed by the Westinghouse interests. In his investigations he realized that mercury was of such a nature as to permit of rectification from a.c. to d.c. In April 1900, he perfected his first rectifier, the patents for which were secured in Jan. 1902.

At present there are some half dozen methods of obtaining direct from alternating current, all of which have disadvantages connected with them. Many of these disadvantages practically disappear, however, in the case of the mercury rectifier.

In the first place the motor-generator set is quite frequently used for the a.c. to d.c. transformation. This however is high in first cost and requires large floor space for installation. The efficiency at full load of sets of proper size for charging vehicle batteries has been comparatively low, and at light loads very low. In the case of high voltage d.c. for constant current series arc lights it would be impossible to obtain proper commutation on the d.c. machine, hence the operation of a number of series lights from a motor-generator set is an impossibility.

The single phase rotary converter is another method of rectification. However, it is not as flexible as the motor-generator set, particularly as regards voltage, and it requires more care and higher intelligence in starting and operating it. Besides, as in the case of the motor-generator set, we cannot commutate a sufficiently high d.c. voltage to maintain a set of series arc lamps.

Together with the above two most important methods we have a number of others which have proved more or less unsatisfactory under certain conditions. These include The Synchronous or Mechanically Driven Rectifier, sometimes called the Lethuele Rectifier, the Chemical Rectifier, in which aluminum is the important substance, due to its peculiar polar resistance; and Switching Devices for Rectification. There are also various forms of Electrolytic Rectifiers involving substances such as tantalum, carborundum, etc.

There are two distinct types of mercury rectifier, namely, low tension and high tension types. The storage battery charging outfit is a typical example of the first form where the pressures run below 300 volts.

The low tension set consists essentially of:

(a) An auto-transformer for excitation.
(b) A direct current reactance.
(c) The rectifier bulb and holder.
(d) An operative panel.
(e) A regulating reactance.

The auto-transformer, or compensator reactance, as it is sometimes called, is simply used to step the line voltage up or down a sufficient amount to give the desired terminal a.c. volts across the bulb. It consists in principle of two coils of an equal number of turns connected in series with one another, the middle point being connected through the d.c. load to the cathode. This is shown in Fig. 1.

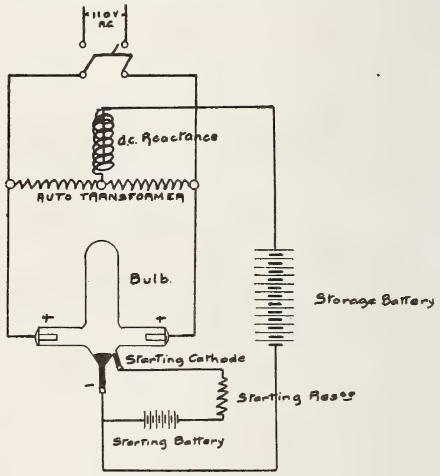


Fig 1

CONNECTIONS FOR LOW TENSION APPARATUS

In order to smooth out the otherwise rapidly fluctuating waves and also to cause the instantaneous current in one anode or cathode circuit to overlap the instantaneous current in the other by a small angle usually about 20°, we have sometimes a d.c. reactance in series with the d.c. load.

The Bulb and Holder.

The bulb or tube is a glass vessel exhausted to a high degree and sealed at the tip, the vacuum being necessary for the unimpeded flow of current. It is equipped with two anodes, one cathode, and one starting anode. The cathode and starting anode are filled with mercury. The production of the conducting vapor takes place at the surface of the cathode from what is known as the cathode spot. This cathode spot or bubble continually wanders around on the surface of the mercury cathode.

The size and shape of the bulb depends almost entirely on its capacity in amperes and volts, since it can be easily seen that higher voltage types require more protection against spatterings of mercury, and the consequent injurious effects from this cause, than the low voltage types; while the cross sectional area depends on the current required.

The rectifier bulb is supported at the back of the board by a holder consisting of a metal frame so pivoted at its centre that it can be rocked back and forth. The life of the bulb under normal operating conditions is at least 400 hours unless defective in manufacture. In fact the life of the bulb is almost a matter of guesswork unless perhaps it refuses to operate at all. Tests so far have shown an average of

3000 hours for the 10 ampere tubes.
2500 hours for the 20 ampere tubes.
700 hours for the 30 ampere tubes.

On the operating panel are mounted usually voltmeter, ammeter, double throw switches for connection to the supply and load circuit, and the necessary double pole and single pole switches for starting and operating the rectifier. Fuses and circuit breakers are provided for protecting the bulb against overloads. A starting resistance is mounted on one of the pipe supports and is connected in multiple with the pilot lamp mounted on the front of the board. The pilot lamp is used to indicate that the rectifier is in operation, and also acts as a warning that the starting resistance switch should be opened as the load is thrown on, as the lamp is dark when the rectifier is operating on the load only. The necessary reactance dials are also provided. The connections behind the panel can be seen in Fig. 2.

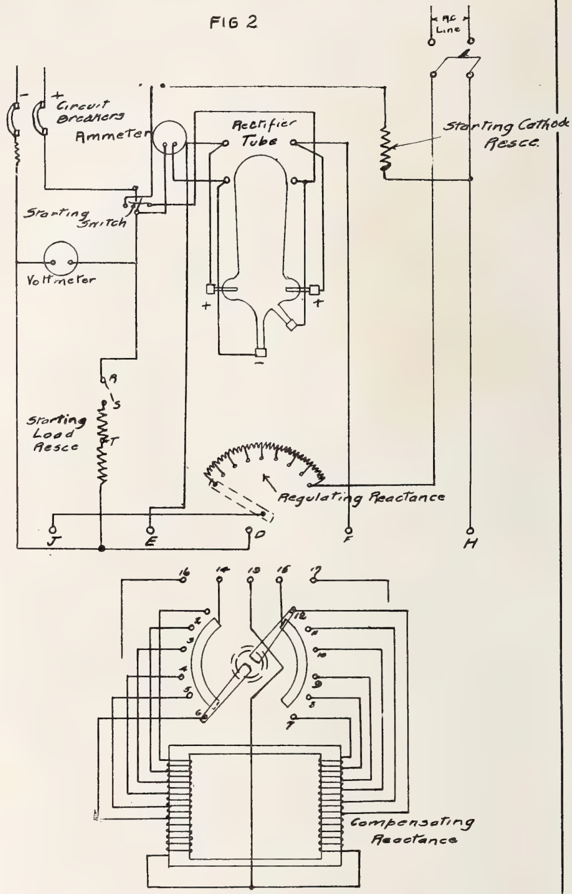
A smoother or finer control of d.c. voltage as well as current is obtained by a regulating device in series with the a.c. supply line and mounted on the pipe support back of the panel. It consists of a coil wound on a laminated iron core, a number of taps are taken from this coil and connected to a semi-dial switch mounted on the panel.

The high tension series arc lighting type consists of the following apparatus:

1. A constant current transformer.

CONNECTIONS OF SINGLE PHASE MERCURY RECT. PANEL

FIG 2



Connect J to 16; E to 14; D to 13; F to 15; H to 17

110 V ac Line Voltage	For 15 to 30 volts d.c. Connect	16 to 1; 17 to 7, A to T
	For 30 to 46 " "	16 " 6, 17 " 12, A " S
110 V ac. – 220 V Line Voltage	Use 110 V ac " 30 - 45 " "	16 " 6; 17 " 12; A to T
	Use 220 V ac " 40 " 75 " "	16 " 1; 17 " 7, A to S
220 V a.c. Line Voltage	For 45 " 75 " "	16 " 1, 17 " 7, A to T
	" 75 " 115 " "	16 " 6; 17 12; A " S
330 V a.c. Line Voltage	" 90 " 120 " "	16 " 1; 17 " 7; A " T
	" 120 " 175 " "	16 " 6, 17 " 12, A " S

Plate 2

2. A d.c. reactance.
3. An exciting transformer for starting.
4. The rectifier bulb.

The transformer is of the usual constant current type, consisting of a three-legged laminated magnetic core, the middle leg of which is surrounded by two flat secondary coils fixed in position, and by a primary coil suspended on a rocker arm.

The d.c. reactance is tapped off the neutral of the transformer secondaries which acts the same as in the case of the storage battery charging apparatus, to store up and give out energy and hence to smooth out the waves. The exciting transformer consists merely of a step-down transformer exciting the primary. The secondary terminals are connected to the cathode and starting anodes.

The high tension bulb is similar to those described previously although, being of high voltage, it must necessarily have better protection for its anodes. The entire apparatus in an assembled form for arc lighting service is shown in Fig. 3.

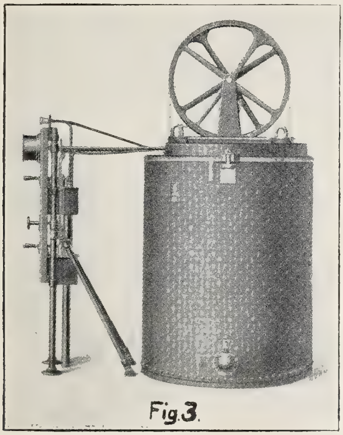


Fig. 3.

The large tank in the cut is filled with transformer oil and not only provides for a cooling effect on the bulb and other portions of the apparatus but also acts as a high tension insulator. About 90° F. is the best temperature for operation, the lower limit being about 50° F.

The action or principle of operation of the mercury rectifier is a subject upon which experts seem to vary a great deal. In fact three distinct theories are developed for its action, namely, the Steinmetz arc theory, the Thomas cathode resistance theory, and the Wagoner ionization theory. Of these three the Wagoner theory seems to be the easiest to follow. It maintains that the action of the rectifier tube is based on the production of negatively charged ions at the cathode spot. These ions can be deprived of their negative charges only at a positive electrode. Since there exists in the tube no means of producing negative ions at the anodes, for the very reason that there happens to be no mercury at the anodes, the current passes in one direction only in the arc stream. The unidirectional passage of current is not a property of the mercury vapor (which under ordinary circumstances is not a conductor at all), but is the result of the employment of ion producing cathodes and anodes, which do not produce negative ions, but merely relieve such ions of their charges. Should an ion producing spot, or cathode be established accidentally on either anode, current would pass or arcing would take place from one anode to the other as already described, causing a short circuit of the tube. The flow of current in the rectifier can best be discussed with reference to Fig. 4. Assume an instant when the terminal H of the supply transformer is positive. Then the anode A is positive and the arc is free to flow between A & B. Following the direction of the arrows still further the current passes through the load J, through the reactance coil E, and back to the negative terminal on the transformer, G. A little later, when the impressed E. M. F. falls below a sufficient value to maintain the arc against the counter E. M. F. of the arc and load, the reactance E which has hitherto been charging, now discharges, the discharge current being in the same direction as formerly. This serves to maintain the arc in the rectifier until the E. M. F. of the

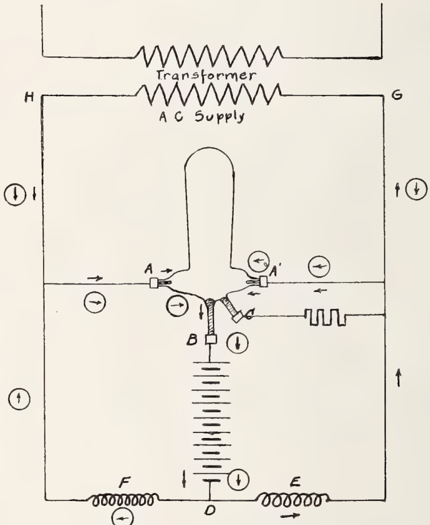


FIG 4

DIAGRAM REPRESENTING FLOW OF CURRENTS IN RECTIFIER
(Wagoner Theory)

supply has passed through zero, reverses, and builds up to such a value as to cause A^1 to have a sufficiently positive value to start an arc between it and the mercury cathode B.

The discharge circuit of the reactance coil E is now through the arc A^1 B instead of through the former circuit. Consequently the arc A^1 B is now supplied with current, partly from the transformer and partly from the coil E. The new circuit from the transformer is indicated by arrows enclosed in circles.

Methods of Starting.

There are several methods for starting the rectifier, or for causing the evaporation of the mercury. The common one is that of starting a spark to jump by breaking contact between the mercury in the starting anode and the cathode by shaking the tube and thus giving consequent vaporization. Or, the above is sometimes performed automatically by magnetic coils. A third in use is the aluminum starting method—where a coating of aluminum on the outside of the cathode is connected through a condenser to the anode, causing the mercury and glass at the cathode to be of opposite polarity; hence causing sparking with resultant vaporization.

Frequency and Power-Factor.

The frequencies possible on the mercury arc rectifier are really those which it is possible to apply to the transformer. However, standard outfits will operate satisfactorily on any frequency from 25 to 140 cycles, although they are usually designed for 60 cycles. The variation in frequency would, of course, depend on the other apparatus including transformers, reactance, etc. The power-factor of the system is about .9, depending on the amount of reactance in and out of the circuits.

Efficiency.

To illustrate the economical efficiency of the battery charging rectifier over the motor-generator set, let us consider an example. Suppose each to be charging a 44 cell battery, the operation being performed in accordance with conditions of time and current recommended by the manufacturer. The first part of the charge is to be at 28 amperes and 106 volts (average) for 5 hours. The efficiency of the motor-generator set at this load is 62%, and of the rectifier set at the same load, 80%.

The second part of the charge is at 12 amperes, and 108 volts (average) for two hours. In this case the efficiency of the former set is 36%, and of the rectifier 81%.

In the motor-generator set the first part of the charge requires 23.93 K. W. hours and the second part 7.2 K. W. hours from the service mains, or a total of 31.13 K. W. hours during the charge. Considering power to cost 6 cents per K. W. hour, the cost per charge amounts to $1.867.

In the case of the rectifier, the first section of the charge requires 18 K. W. hours, and the second part 3.2 K. W. hours from the service mains, making a total of 21.7 K. W. hours. At 6 cents, the cost per charge is $1.302. This shows a saving of 56½ cents per charge by using the rectifier.

Assuming the minimum life of the bulb to be 400 hours, an average of seven hours per charge allows the bulb to experience 57 charges. During this time the total saving amounts to $32.20.

Of late, rectifiers have been applied to numerous uses besides those of battery charging and constant current series arc lighting. Among them are the following: railway signals and car lighting, telegraph systems, fire and police alarm systems; motor-boats, hotel annunciators; chemical laboratory and electrolytic work, electroplating; surfacing and casting machines, elevator purposes, etc.

The many advantages of the apparatus, such as simplicity of operation, economy of initial cost, high efficiency of conversion, long life of rectifier bulbs, and fine gradations of current adjustment throughout the full range, are increased by absence of moving machinery, small space to be occupied, etc.

The outlook for the rectifier is brilliant. Its advancement has surprised even the most optimistic manufacturers. Should its construction in the future be so imposed as to allow of high commercial currents, it will undoubtedly become a central station necessity.

WATER WHEEL GOVERNORS.

E. R. FROST, B.A.Sc.

The ideal turbine governor would be one that would effect a change in output by varying only the quantity of water supplied to the wheel, thus obtaining perfect water economy by conserving unneeded water for future use. This is not possible in practice, as head water, and therefore efficiency, are usually wasted when operating a wheel under other than its normal load.

The success of the comparatively recent application of hydraulic power to the operation of alternators in parallel, and to the generation of current for electric lighting, street railway and synchronous motor loads has been largely dependent upon the possibility of obtaining close speed regulation with good water economy and without undue shock upon machinery and penstocks, while working under extremely varying loads.

While the development of automatic governing apparatus has been almost entirely experimental, remarkable results have been attained, so that some of the modern turbine governors under favorable conditions operate quite as well as modern steam engine governors.

If we consider for a moment the problem of governing a turbine we shall see that it is not at all so simple a matter as would at first appear.

The conditions of the installation have a marked effect on the difficulties to be overcome in turbine governing. If the wheel is set in an open flume having only a short draft tube, so that the water flows to the gates from every direction, the velocity of flow from any direction is very low. The quantity of water which moves at a high velocity is confined to the wheel and draft tube, and a change in the velocity and momentum due to a change in the gates produces no serious effects.

If, however, the water be brought to the wheel in a long penstock, and leaves in a long draft tube, the conditions become quite different. A large amount of energy is stored up in the moving column of water, and if an attempt is made at too rapid regulation the wheel will be left deficient in energy when more power is desired, or when the power is decreased, may produce shocks that will seriously affect the regulation or may cause serious damage to the penstock and wheel.

If the load on the wheel is decreased, the velocity of the water in the penstock must be decreased, and vice versa; work must be done on the water to accelerate it, and must be absorbed to retard it. The work required to accelerate the water must be obtained at the expense of the work done upon the wheel. Thus, when a load is thrown on the unit and the governor opens the gates, the immediate effect is a decrease in the output of the wheel, even below its original value, which is just opposite to the effect desired. Unless energy in some form is available to partially supply this deficiency, the speed of the wheel will fall considerably before readjustment to normal conditions can take place.

In the same way energy must be absorbed when the load is decreased. If this is expended on the wheel the speed will rise above normal. It may be partly dissipated by such means as relief valves or standpipes.

The water in the draft tube must also be accelerated or retarded at each change of gate at the expense of power output in exactly the same way as that in the penstock.

Since the immediate effect of the gate motion is the opposite to that intended, the governor to work properly must be made to anticipate the amount the gate must be moved to bring the speed back to normal. It must move just this far, or a little farther, and then stop and wait for the speed to return to normal.

The governor which does this is said to be "dead beat," or is compensated. Most governors of the later types, as will be shown later, are so constructed that adjustments may be made to give the degree of compensation desired. The speed of the ordinary wheel is away from normal two or three seconds, and since the best large hydraulic governors can make a full stroke in two seconds or less, it will be seen that unless the governor were compensated the gate would be entirely opened or closed long before the speed were back to normal, with the result that the wheel would race.

The different makes of governors are distinguished by their different mechanisms for compensating, and some of them have been brought to such perfection that to see one of them operating, one would almost think the machine provided with brains.

Before taking up the construction of governors it might be well to look into some of the conditions effecting regulation.

Water Hammer.—"If the closure of the gates is rapid, the column of water in the penstock is set into vibrations or oscillations, which in a long pipe under high heads is very dangerous to the wheel and penstock. If the partial gate closure is slow enough each increment in pressure is gradually dissipated along the pipe, and the hammer is avoided.

The extinction of a velocity of four feet per second at a uniform rate in one second in a pipe 1,600 feet long would create a pressure head of about 200 feet, or a total longitudinal thrust on the pipe line at each bend and upon the wheel gate of 24 inches in diameter of about 20 tons.

Hence it is seen that gate movements must be sufficiently slow to avoid dangerous oscillatory waves. This has to be decided for each plant depending on the conditions existing.

To take care of sudden pressure, relief valves and standpipes are often used.

In cases where the head is not very great, say up to 80 or 100 feet, stand-pipes are generally best, as they are certain of operating, and do not waste water. A stand-pipe is simply a large pipe built upright from the main penstock as close to the wheels as possible. It is open at the top, so that the water may rise and fall in it with the variation in pressure in the penstock. A stand-pipe answers two purposes: (1) As a relief valve, and (2) as a storage of energy to take care of sudden increases of load while the water is accelerating and to dissipate the excess kinetic energy in the moving column of water at a time of sudden drop in the load. For these purposes it should be as near the wheel as possible, and of ample diameter.

When the head gets over 100 feet it is impracticable to build stand-pipes owing to the cost of building a structure high enough and strong enough to withstand the wind pressure, and also because the inertia of the long column of water in the standpipe will give rise to strains as injurious as those they are designed to relieve.

A relief valve is arranged to open when the pressure rises above a set value and allow water to waste into the draft tube or other convenient place. An ordinary valve, such as that used for steam, would open and close so rapidly as to act like a reed upon an organ pipe, and thus maintain and increase the vibration of the mass. In order to be at all effective the valve must be dead beat. Though it must open quickly, it must close very slowly. Relief valves are now made, generally of the hydraulic type, which will open instantly and take several minutes to close, the speed of action being, of course, adjustable. Although means have thus been found for relieving the penstock of excessively high pressures, no means have yet been found for quickly accelerating the water when because of an increase in load the speed begins to fall. As already explained, when the governor opens the gates, the inertia of the mass cannot keep pace with the increased demand for water, with the result that the pressure drops, and the speed of the wheel will drop still farther. This may continue for several seconds till the water column has become sufficiently accelerated to supply the needs of the wheel.

If the governor is not made very dead beat the gates by this time will be open too wide, with the result that the speed will go too high, causing the governor to close the gates quickly, so that the relief valves will operate, which, of course, will result in very poor speed regulation.

If the governor is made dead beat enough to avoid pressure oscillation the speed regulation will be poor if the load changes are large and sudden. It is impossible for this to be otherwise, because the column of water cannot possibly alter the energy given to the wheel fast enough, whether the gates be in one position or another.

The only complete remedy for the troubles in speed regulation caused by excessive inertia of a water column is some form of by-pass valve directly connected with the water wheel gates and arranged to open when they close, and thus keep the velocity of the water nearly constant.

This would be equivalent to an impulse wheel arranged with a deflecting nozzle. It would, of course, be very wasteful of water, and in most installations could not be used.

A modification of this principle is used at Turbine, Ontario. In this case the valve, or by-pass, is indirectly controlled by the movement of the governor. The gate-controlling rack which is moved by the governor piston is extended by a piston rod having a piston on its end placed in a cylinder filled with oil. From either end of this cylinder pipes are taken to a controlling piston which operates the relief valve exhausting water from the wheel case into the draft tube. Hence any movement of the governor piston will affect the relief valve. When the governor closes quickly the valve will open, and a movement in the opposite direction will close it. As it is not desirable to have the relief valve open for small movements of the gates the cylinder is provided with an adjustable by-pass so that unless the governor makes a sudden movement of some length the oil will pass from one end of the cylinder to the other.

The small cylinder operating the valve is also provided with a by-pass so that the pressure is gradually reduced, allowing the valve to close. It was found when using this arrangement that the valve had a tendency to stay open too much, owing partly to the pressure of the water on the face of the valve. A large spring was then put behind it to insure of its closing. The by-pass, of course, regulates the speed of closing.

Governors.—To pass on now to a description of a few types of governors:

In all reaction turbines, and in all impulse turbines, with the exception of tangential wheels, the governor controls the speed by opening or closing the regulating gates, thus varying the amount of water supplied to the wheel.

As a large force is necessary to move the gates (sometimes 50,000 pounds), it is clear that they cannot be moved by fly balls alone, as in the case of a steam engine. Consequently some form of relay mechanism has to be used. That is, the movement of the balls controls some independent power for moving the gates. There are two classes of governors, viz., mechanical and hydraulic, each being classified by the type of its relay mechanism. In the mechanical type the power to move the gates is supplied by the wheel itself by means of belts, friction clutches, gears, etc. The fly balls throw into action pawls, friction gears, or other mechanical devices which will bring the relay into action. When the relay is of the hydraulic type it generally consists of a piston connected by some mechanical device to the gate rigging and moved by means of the hydraulic pressure of the water taken from the penstock or other source or by oil supplied under high pressure from a reservoir, usually the latter.

The pressure of the oil in the reservoir is kept up by pumps driven either from the wheel itself or by a separate motor. The oil used in moving the piston is exhausted into a receiver and pumped back into the supply reservoir. The relay is usually controlled by the ball governor, through the medium of a small valve, which by its motion admits the oil or water directly to the main piston or else to a secondary piston which controls a larger admission valve.

The mechanical governor is cheaper to build, and probably requires less attention than the hydraulic type, but on the other hand, it takes power from the wheel just at the time when more power is needed. It is also slower, and in the case of some wheels whose gates have a tendency to close themselves, a constant rubbing of the friction wheels is necessary to keep them open. Where the wheels operate factory machinery or machinery of that class, the mechanical governor is generally quite satisfactory and also cheaper to install.

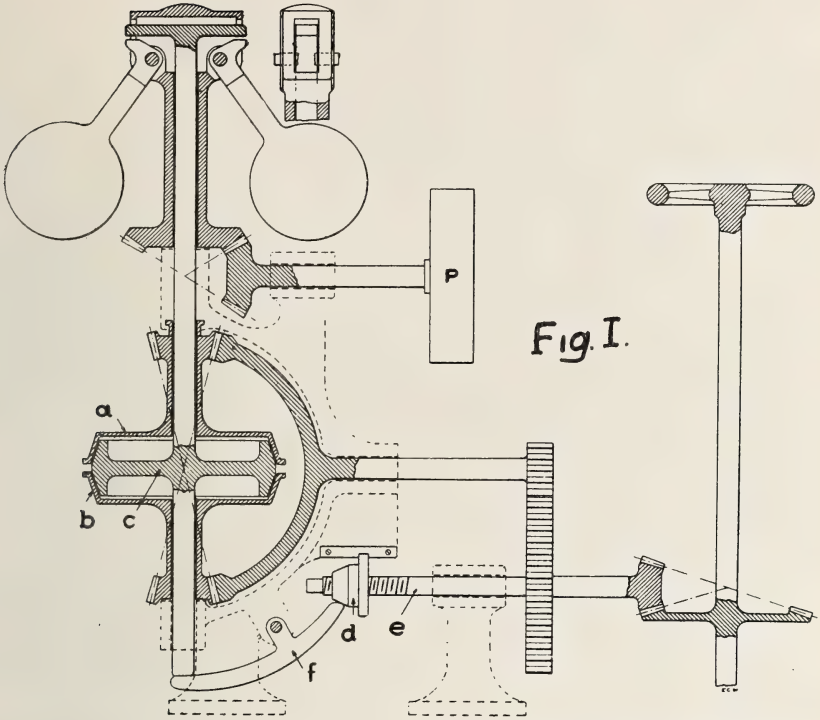


Fig. 284.—Diagramatic Section of Woodward Simple Mechanical Governor,

Fig. 1 shows a simple form of mechanical governor, made by the Woodward Governor Co., Rockford, Illinois.

On the upright shaft are two friction pans (a and b). These pans are loose on the shaft, the upper one being supported in position by a groove in the hub, and the lower one by an adjustable step bearing. Between these pans, and bevelled to fit them, is a double-faced friction wheel (c) which is keyed to the shaft. This shaft and friction wheel run continuously, and have a slight endwise movement. They are supported by lugs on the ball arm, and therefore rise and fall as the position of the balls varies with the speed.

When the speed is normal, the inner, or friction wheel, revolves freely between the two outer wheels or pans, which remain stationary. When a change of speed occurs the friction wheel is brought against the upper or lower pan as the speed is either slow or fast. This causes the latter to revolve, and by means of the bevel gearings, turns the gates in the proper direction until the speed is again normal. As the gate opens, the nut (d) travels along the screw (e) which is driven through gearing by the main governor shaft, and as the gate reacts, the nut (d) coming in contact with the lever (f) throws the vertical shaft upward and the governor out of commission. This governor is not dead beat, but where load changes are not very rapid or frequent, the governor works quite satisfactorily, and requires almost no attention. It may be used to advantage on exciters in small plants and for light work. The Woodward Co. also make a compensating governor of the mechanical type, but as space is limited, it will be necessary to show only one of each class.

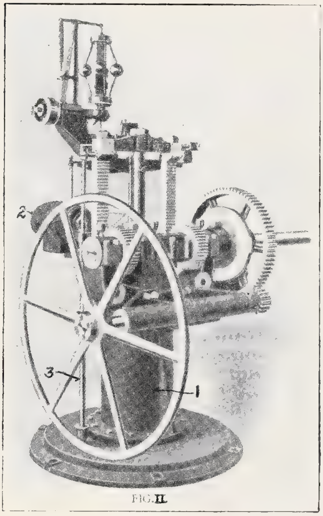


FIG. II

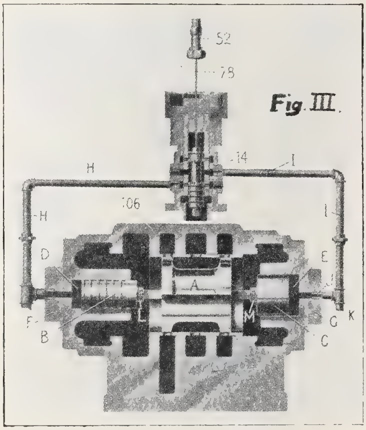


Fig. III.

Fig. 2 shows the Lombard Governor Co.'s Type N governor.

It will be seen that the main working cylinder (1) is vertical, and that the movement of the piston up or down is transmitted through the double rack and pinions to the operating shaft. The balls control a small regulating valve, 14, Fig. 3, which admits oil from the pressure tank to the relay valve, 2. At 3 is seen the displacement cylinder with its piston connected rigidly to the rack bars.

Fig. 3 is a section of the relay valve, 2. Its method of operation is as follows:

A is the relay valve, which may be moved in either direction by the plungers B and C. Since the plunger B has one-half area of plunger C, the latter can overpower the former if the pressures in the cylinders E and D are equal. Cylinder D is connected through pipe H to the pressure supply; hence the tendency of B is always to move valve H towards the valve head G. Oil is exhausted or supplied through the pipe I. K leads to the displacement cylinder, while H is connected with the pressure tank. When valve 14 is moved by balls in one direction it admits oil from pressure tank to I, forcing A to left, which admits oil to lower side of main piston, and opens the upper side to the exhaust. The main piston rises, moving the wheel gates. In moving up, the displacement piston is carried up, creating a partial vacuum in the displacement cylinder. This draws part of the oil from I through K, and as the piston moves farther, all the oil in I is exhausted, with the result the valve, A, stops. The main piston, however, continues to move as long as valve 14 is open. When this is closed A is closed, because the liquid in cylinder, E, escapes to the displacement cylinder. When A is closed the governor comes to rest.

When 14 is moved in the opposite direction the opposite to the above takes place, so that A moves to the right till the valve, 14, takes a new position. It will be seen that any movement of the regulating valve, 14, is duplicated by the main piston, and that when valve 14 is again in its neutral position, A is immediately closed.

The anti-racing mechanism is not seen in the cut, but is arranged as follows:

The stem of valve 14 is threaded into the head of the fly balls so that any rotary motion given to it will raise or lower it. Any motion of the main piston is transmitted through a reducing motion and dash pot to a small rack engaging with a gear on the stem of valve 14.

When the speed of the wheel gets away from normal, regulating valve 14 is displaced, causing main piston to move. The reducing motion working through the dash pot and rack turns the valve stem so that the valve is closed, bringing the governor to rest to wait for the speed to return to normal. By adjusting the by-pass of the dash pot the governor may be compensated to any degree to suit the particular conditions of the installation. That is, the governor will move the gates just far enough to bring the speed back to normal, and will stop there. The Sturgess hydraulic governor uses an expansive pulley to drive the governor balls. When the main piston moves it carries with it a cam, which through a dash pot actuates a lever, expanding or contracting the pulley, thus bringing the balls back to normal speed before the wheel is actually up to normal speed.

In the case of impulse wheels, which are generally used with very high heads and long penstocks, it is impracticable to build penstocks which are strong enough to withstand the shocks due to sudden closures of gates, hence a deflecting nozzle is used. That is, the nozzle is hinged, and when it is desired to decrease the output, the nozzle is deflected from the blades. If the needle valve is set to carry peak loads there will be a waste of water at all other loads. This condition is commonly improved somewhat by adjusting the needle valve about once an hour, by means of a slow motion hand wheel, for the maximum load liable to occur during that period. An automatic governor has lately been invented, which adjusts the needle valve slowly automatically, so that the stream is kept on the blades. This is done by the use of an electric motor, a connection being made which starts the motor as soon as the nozzle deflects. The motor is geared to move the valve slowly. In large installations employing hydraulic governors it is generally the custom now to have one set of pumps and pressure system to supply all the governors in place of having a separate pump and tanks for each governor. This has the advantage that only one pump and pressure system have to be kept up, but on the other hand, should this pump fail, all governors are out of commission. This is generally overcome by having a duplicate pressure stystem to take the place of the working system while repairs are made or while the first system is being cleaned out. The different companies making governors supply special oil, but they do not seem to have yet found an oil which will stand up under the continued surging around the system. A substance like cement forms in the bottom of the tanks and piping which is very difficult to remove. Some good work might be done in experimenting along this line.

REPORT OF DUTY TRIAL ON THE SIX MILLION IMPERIAL GALLON PUMPING ENGINE AT THE HIGH LEVEL PUMPING STATION, TORONTO WATER WORKS.

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Professor of Mechanical Engineering.

The city of Toronto has two pumping stations for the supply of water to the city proper, exclusive of that supplied to the residents of Toronto Island. Of these two the main pumping station is situated at the foot of John St., close to the bay, and all the water supplied to the city passes through pumps in this station, the pressure being maintained at slightly over 90 pds. per sq. in.

As the ground rises very rapidly as one proceeds northward from the bay, the pressure in the northern part of the city produced by the pumps at the main pumping station, would be rather low and in the district near the Canadian Pacific Railway does not much exceed 21 pds. per sq. in.

In order to maintain the proper pressure in the northern part of the city the High Level Pumping Station was built on Poplar Plains Road a short distance above the Canadian Pacific Railway tracks.

The growth of the northern part of the city has been very rapid of late years and the consequent consumption of water

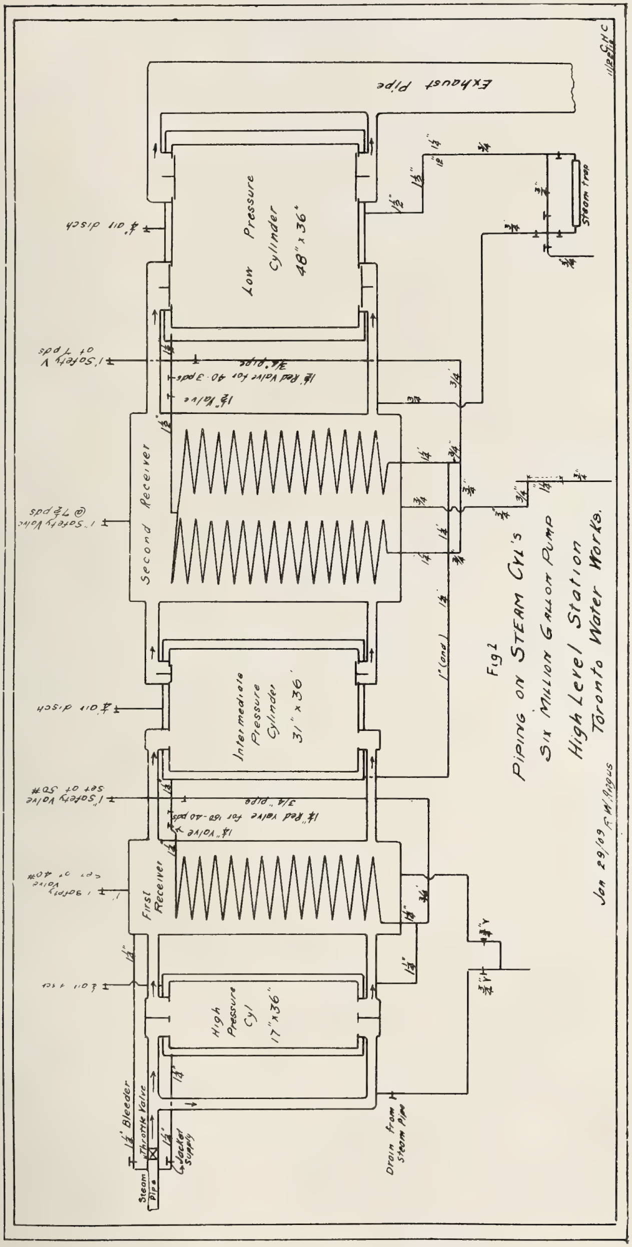


Fig 1
Piping on Steam Cyl's
Six Million Gallon Pump
High Level Station
Toronto Water Works.
Jan 29/09 F. W. Angus

has so increased that the pumps originally installed in the station were unable to maintain a sufficiently high pressure, so that an additional pump, having a capacity of six million Imperial gallons per day against a pressure of 75 pds. per sq. in., has been installed and it is this latter pump with which this report deals.

Description of the Engine.

The engine tested is a three-cylinder, vertical, triple-expansion crank and fly-wheel pump having three single acting plungers direct-connected to the pistons of the three steam cylinders. It is designed to give a discharge of six million Imperial gallons per twenty-four hours against a discharge pressure of 75 pds. per sq. in. for domestic purposes but is also capable of giving the same discharge against a pressure of 100 pds. per sq. in. for fire purposes.

The nominal diameters of the steam cylinders as given on the working drawings, are 17 in., 31¼ in., and 48 in., respecttively and the nominal diameter of all water plungers is 21¾ in., the stroke for all plungers and pistons being 36 in. For the duty trial the diameters and strokes of the water plungers were determined with great care, as is explained later, but the dimensions of the steam cylinders were not verified.

To the crosshead of the low-pressure plunger are attached the feed pump, the air pump, and an air compressor for providing compressed air in the discharge air chambers and also for the operation of the steam cylinder poppet valves if desired.

The engine has three cranks placed 120 degrees apart, the sequence being high pressure, low pressure and intermediate pressure. The crank shaft is made in two parts, which are joined together at the central crank by a sliding block which gives the shaft some flexibility without affecting its working.

Steam cylinders and piping.—A diagram of the steam piping for the engine is given at Fig. 1, which shows the main steam piping as well as that for the jackets and reheaters. Each of the cylinders is provided with a steam jacket and receivers are placed between each pair of cylinders, a reheating coil being placed in each of the receivers. The sizes and arrangement of pipes are shown on the drawing and are as follows:

(a) *Cylinder-Steam piping.*—After passing the throttle valve the steam main has two five-inch branches one of which carries steam to the top of the high pressure cylinder, the other to the bottom of the same cylinder. The exhaust from the high pressure cylinder is conveyed by two pipes, each 5 in. diameter, to the first receiver where it is reheated before being delivered to the intermediate cylinder through two pipes each 8½ in. diameter.

From the intermediate cylinder the steam passes through two pipes into the second receiver where it is again reheated before being sent to the low-pressure cylinder. After passing through the latter cylinder the steam is conveyed by the 16 in. exhaust pipe to the heater and finally to the condenser.

(b) *Jacket and reheater piping.*—The jacket supply is drawn from the main steam pipe on the boiler side of the throttle valve by means of a 1¼ in. pipe, which pipe contains a valve and connects directly with the high pressure jacket.

On leaving the high-pressure jacket the steam passes, by means of a 1¼ in. pipe, to the reheating coil in the first receiver, from which it is conveyed through a 1¼ in. pipe containing a 1¼ in. globe valve and a 1¼ in. reducing valve, (set for reducing the pressure from 150 pds. to 40 pds.), to the intermediate jacket. This 1¼ in. pipe also contains a 1 in. safety valve set at 50 pds.

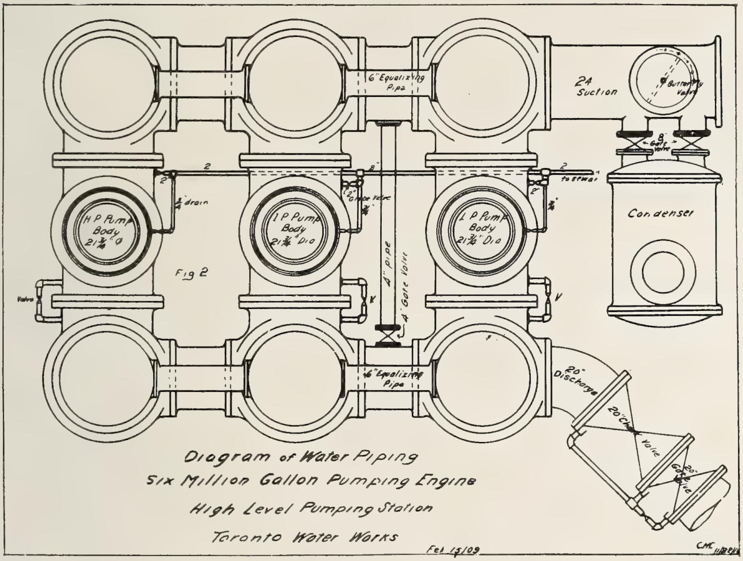


Fig 2

Diagram of Water Piping
Six Million Gallon Pumping Engine
High Level Pumping Station
Toronto Water Works
Feb 15/09

After passing through the intermediate jacket the steam passes through a 1 in. pipe which is enlarged to 1¼ in. into the two reheating coils in the second receiver, which coils are arranged in parallel. The steam leaves these coils through a single 1½ in. pipe, on which is a globe valve, a 1½ in. reducing valve set for reducing the pressure from 40 pds. to 3 pds., and a safety valve set at 7 pds. This 1½ in. pipe delivers the steam into the low pressure jacket.

On leaving this jacket a 1½ in. pipe, which is reduced to 1¼ in. and finally to ¾ in. delivers the steam to a trap from which it passes by a ¾ in. pipe to the sewer.

For drainage from the jackets and receivers and the reheating coil ¾ in. pipes are arranged as shown.

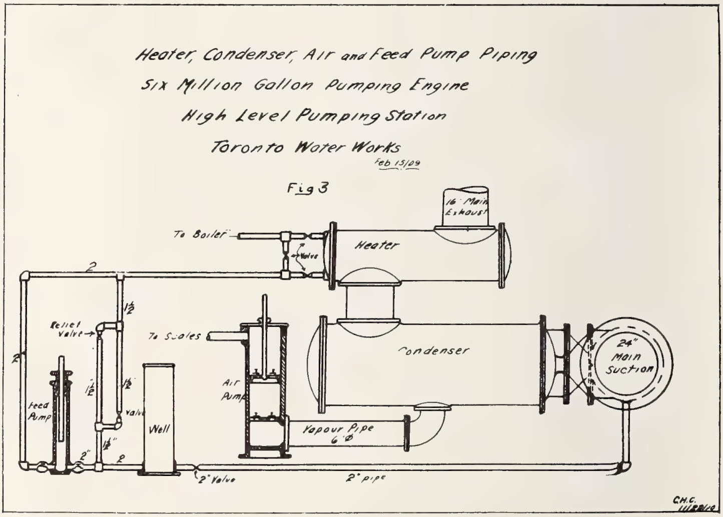
(c) *Other piping.*—A 1¼ in. pipe is connected from the main steam pipe on the boiler side of the throttle to the first receiver for starting up. This pipe contains a 1¼ in. globe valve.

Air discharge pipes each ¼ in. diameter and supplied with a valve are placed at the top of each cylinder jacket.

A 1 in. safety valve set at 40 pds. is placed on the first receiver and a similar valve set at 7½ pds. on the second receiver.

The high pressure cylinder has Corliss admission and exhaust valves, and on the intermediate cylinder Corliss admission valves are used, while for the exhaust for this cylinder and the admission and exhaust for the low pressure cylinder poppet valves are used.

The speed of the engine is controlled by a flyball governor which operates on the high-pressure valves only and in case the speed becomes excessive this governor also opens a valve in the condenser so as to admit air to the latter and "break" the vacuum.



Feed Water and Condenser Piping.

The feed water and condenser piping scheme is shown on Figs. 2 and 3.

The cooling water for the condenser is taken from and again returned to the suction pipe of the engine. A butterfly valve is placed in the main 24 in. suction pipe and the cooling water is drawn from this pipe, on the side of the butterfly valve remote from the pump, through an 8 in. valve and pipe passing into the condenser. After passing through the condenser the water is returned to the suction main through an 8 in. pipe and valve but on the side of the butterfly closest to the engine. By the proper adjustment of the butterfly valve any desired proportion of the water may be sent through the condenser.

The area of the butterfly valve is about 80% of the area of the 24 in. pipe but it is never set at less than 22½° to the normal to the pipe axis and when fully open is turned parallel to the pipe axis in which case it offers practically no resistance to flow and very little water would pass through the condenser.

The exhaust steam first passes through a feed water heater and then on to the condenser. After being condensed the steam passes through a 6 in. pipe to the air pump from which it is discharged to the sewer.

The feed water is drawn from the main suction pipe through a 2 in. pipe, containing a valve, into the well. From the well a 2 in. pipe delivers the water to the feed pump from which it is discharged through a 2 in. pipe. As shown on the drawings the water may be sent through the heater or not as desired. A by-pass of 1½ in. pipe and containing valves is connected from the suction to the discharge pipe of the feed pump.

Main Water Piping.

The water enters the pumphouse through a 24 in. pipe containing a gate valve close to the wall of the room. It then passes down the south side of the engine supplying water to the suction air chambers. After passing through the pump cylinders the water is discharged at the north side of the pump through a 20 in. pipe containing a check valve and a gate valve.

A 4 in. by-pass pipe with valve may be used to connect the suction and discharge sides of the pump if desired. This pipe is placed between the intermediate and low pressure parts of the engine.

Equalizer pipes, 10 in. diameter, connect the three suction air chambers and similar pipes connect the discharge air chambers. Air is forced into the discharge air chambers by means of the air compressor attached to the low-pressure crosshead.

The remainder of the piping consists of a 2 in. pipe with valve connected to the plunger chamber and free to discharge into the sewer provided the valve is open. The valve is controlled by a wheel on the engine room main floor. There is also a 2 in. by-pass from the plunger chamber to the discharge chamber of each pump. This pipe also contains a valve which may be opened by a hand wheel on the main floor.

Pumps.

The pumps are single-acting, and corresponding to each plunger there is one suction and one discharge chamber. The valves are arranged in cages, there being for each plunger seven valve cages, each cage containing 25 valves. There are thus 525 suction valves and 525 discharge valves.

The area through each of the valves is given on the drawings as 5.95 sq. in., but this was not verified.

NOMINAL DIMENSIONS OF ENGINE AND PUMPS.

Note:—The dimensions given in the following table are all taken from the working drawings but were not verified, as they are not essential to the duty trial. The exact diameter and stroke of each plunger is given elsewhere, but the sizes given on the drawings are set down here for convenience.

1. Nominal Dimensions of the Engine.

High Pressure Cylinder:—

Diameter of piston	in.	17
Diameter of counterbore of cylinder	in.	17⅛
Diameter of piston rod	in.	4
Stroke of piston	in.	36
Clearance (least distance from piston to cylinder head)	in.	¼

Intermediate Pressure Cylinder:—

Diameter of piston	in.	31¼
Diameter of counterbore of cylinder	in.	31 5-16
Diameter of piston rod	in.	4
Stroke of piston	in.	36
Clearance (least distance from piston to cylinder head)	in.	¼

Low Pressure Cylinder:—

Diameter of piston	in.	48
Diameter of counterbore of cylinder	in.	48⅛
Diameter of piston rod	in.	4
Stroke of piston	in.	36
Clearance (least distance from piston to cylinder head)	in.	¼

First Reheating Receiver:—

Diameter of two steam pipes entering	in.	5
Diameter of two steam pipes leaving	in.	8½
Volume of receiver	cu. ft.	33.5
Size pipe in reheating coil (o.d. copper tubing)	in.	1¼
Number of coils		1
Number of turns per coil		18
Mean diameter of coil	in.	24
Heating surface in coil	sq. ft.	37

Second Reheating Receiver:—

Diameter of two steam pipes entering	in.	8½
Volume of receiver	cu. ft.	47

Size of pipe in reheating coils (o.d. copper tubing)	in.	1¼
Number of coils		2
Number of turns per coil		22
Mean diameter of coils	in.	28
Heating surface in two coils	sq. ft.	64

Condenser:—

Diameter of shell inside	in.	36¼
Diameter of exhaust inlet	in.	16
Diameter of condensed steam outlet	in.	6
Diameter of water conections	in.	8
Tubes No. 16 B. W. G., outside diam.	in.	1
Length of tubes between plates	ft.	5
Number of tubes		228
Cooling surface in condenser	sq. ft.	300

Feed water Heater:—

Diameter of shell inside	in.	16
Length between tube plates	in.	58
Diameter of steam inlet and outlet	in.	16
Diameter of water connections	in.	2
Tubes No. 18 gauge, outside diam.	in.	⅝
Length of tubes between plates	in.	58
Number of tubes		68

Air and Feed Pumps:—

Air Pump—Single Acting.

Diameter	in.	12
Stroke	in.	36
Diameter of inlet pipe	in.	6
Diameter of discharge pipe	in.	8

Feed Pump—Single Acting.

Diameter	in.	1¾
Stroke	in.	36
Diameter of inlet pipe	in.	2
Diameter of outlet pipe	in.	2

Air Compressor:—

Diameter	in.	3
Stroke	in.	36
Water jacket pipes, inlet and outlet	in.	¾

General Dimensions:—

Length of connecting rod, centre to centre	ft.	7½
Diameter of crank shafts in fly wheel	in.	12½
Diameter of main bearings	in.	10½
Length of main bearings	in.	18
Diameter of hole through shaft	in.	3
Crank pins—diameter	in.	6½

Crank pins—length	in.	6
Crosshead pins—diameter	in.	6½
Crosshead pins—length	in.	6
Diameter of steam pipe	in.	
Diameter of exhaust pipe	in.	16
Number of flywheels		2
Diameter of wheels	ft.	12 1-3

Rim 11in. and 12 in. wide, 12 in. thick.

Length of hub	in.	17½
Weight of each wheel	lbs.	20000

2. Nominal Dimensions of the Pumps.

Diameter of plungers	in.	21¾
Stroke of plungers	in.	36

Valves:—

Rubber, arranged on sides and top of cages, secured to deck plates.

Number of valve deck plates		6
Number of holes for cages in each plate		7
Total number of valve cages		42
Number of valves per cage		25
Total valves in entire pump		1050
Water opening in each valve	sq. in.	5.95

(Note—one-half (525) of the above valves are suction, the rest discharge).

Air Chambers:—

Number of suction air chambers		3
Number of discharge air chambers		3

Piping:—

Suction pipe diameter	in.	24
Discharge pipe diameter	in.	20
Equalizer pipes, diameter	in.	10
Number of distance rods to plungers		12
Diameter of each rod	in.	3

The Duty Trial.

According to the specifications and contract, "The engine shall perform a duty of not less than one hundred and sixty million (160,000,000) foot pounds for each one thousand (1000) pounds of commercially dry steam used by the engine and any auxiliary pumps supplied by the contractor and operated during the duty trial. Steam containing less than 1½ per cent. of entrained water, as determined by calorimeter measurements, shall be considered as commercially dry steam. In computing the duty, the work performed by the engine shall be based upon plunger displacement. The head for computing the duty shall be that shown by an accurate pressure gauge attached to the discharge main at a point inside of the engine room and beyond the last pump, less the reading shown by a gauge attached to the supply main at or near the entrance to pump. No allowance shall be made for friction of water in pumps or pipes between the pump well and the gauge attached to the discharge main. In computing the duty, the total steam used, including that used by jackets, reheaters, and auxiliary pumps, shall be charged to the engine. The duty trial shall be of twenty-four hours' duration. The engine shall be operated continuously at the rated capacity against a head equal to 75 pds. pressure per sq. in. on the discharge main, and shall be supplied with steam of not more than 150 pds. pressure per sq. in., by gauge, at the boiler."

"The engine shall have a capacity of six million Imperial gallons in twenty-four (24) hours when operated at a plunger speed of not over 180 ft. per min., against a head equal to 75 pds. pressure per sq. in., on the pumps."

It is further stated in the general data given the contractor that the pressure in the suction main is 15 pds. per sq. in.

The trial was made as closely as possible under the contract conditions; as however, the pressure in the suction main, on account of some alterations in the city water piping system, had been raised to about 25 pds. per sq. in., the pressure on the discharge main during the test was about 85 pds. per sq. in., in order to obtain the pressure difference of 60 pds. per sq. in. between suction and discharge mains contemplated in the contract.

Weight of Steam Used.

The steam chargeable to the engine was determined by the condensation from the condenser, the jackets, the reheater, etc., and tanks were arranged, placed on scales, so that the weight of the condensed steam could be directly determined. The condensation from the condenser was measured by itself in one set of tanks, and that from the jackets and other drain pipes in a second and smaller set. The weights of condensed steam were measured every half hour, two observers checking all weights independently, setting down their results and comparing them before making the entry on the observation sheet.

Pressure.

The pressure on the discharge main was taken by an accurately calibrated Bourdon gauge, the piping leading to which was attached outside the last connecting branch from the pump. The pressure on the suction main was measured similarly by an accurately calibrated Bourdon gauge, the attachment being made close to where the suction main enters the pumping station, just outside of the condenser. The gauges themselves were placed side by side in a position where they could be conveniently read from the engine platform, about fourteen feet above the suction and discharge mains, correction being made for water column. The pressure difference was maintained as closely as possible at 60 pds. by manipulating a gate valve on the discharge main placed outside the point of attachment of the discharge gauge. During the night the pressure on the discharge main became excessive, and in order to maintain the pressure difference at the required figure it was found necessary to open a hydrant adjacent to the station.

The steam pressure at the engine was determined by an accurately calibrated Bourdon gauge, and the pressure in the calorimeter by a mercury manometer.

The pressures in the first and second receivers were taken from gauges on the gauge board. These gauges were not calibrated, but correction was made for water column. The vacuum in the exhaust pipe was taken from the vacuum gauges at the gauge board which was not calibrated.

The pressure in the steam jackets was determined from the regular gauges attached to the jacket, which were not calibrated or corrected in any way.

The barometer reading was obtained from the Observatory at intervals during the test. The result given is the average throughout the 24 hours, corrected to the height of the High Level Pumping Station, and the temperature of the engine room.

Speed.

The speed of the engine was determined by the revolution counter attached to the gauge board, the reading on this counter being checked by a second counter specially set up for the test; the counters agreed perfectly.

The Quality of the Steam.

The quality of the steam was determined by a throttling calorimeter connected to the steam main on the engine side of the throttle valve. The calorimeter worked satisfactorily throughout the test. The percentage of moisture in the steam was low, and showed very little variation throughout. The steam used by the calorimeter was not weighed.

Temperatures.

The temperatures of the engine room and of the boiler room were observed throughout the test.

The temperature of the exhaust was obtained from a thermometer placed in the exhaust pipe about eight feet below where the latter left the engine.

Indicator Diagrams.

Indicator diagrams of the steam and pump cylinders were taken at intervals during the test.

Measurements of the Plunger.

The diameters of the plungers were measured Wednesday, April 7th, the engine being shut down at about 4 p.m. for this purpose. By means of a steel tape, measurements of the circumference of each plunger at each end and at the middle were made. The plunger on the high pressure end was found to taper slightly from the bottom to the top, being largest at the bottom. In computing the diameters and areas of the plungers from this tape measurement, corrections were introduced for temperature, and for thickness of the tape, the tape itself being compared with a Government Standard.

The average diameter of each plunger determined as indicated above was used in computing the plunger displacement.

The strokes of the plungers were measured after the trial. A strip of oak 1½ inches square on which were fastened brackets and adjusting screws was firmly fixed between points on the frame and made parallel with the piston rod. A stout pointer, with a flattened end, the thickness of which was accurately measured, was then firmly clamped to one of the distance rods connecting the pump plunger to the cross head of the engine. The bracket screws were then so adjusted that the lower one just touched the under surface of the flattened pointer at the bottom of the stroke, and the upper one its upper surface at the top of the stroke. The distance between the points of the adjusting screws, less the thickness of the pointer end gave the length of the stroke. In determining the distance between the points of the screws a special bar was used whose length had been ascertained by micrometer callipers.

Calibration of Apparatus.

The steam gauges on the boiler and on the steam supply to the calorimeter, and the water gauges on the suction and discharge mains were calibrated both before and after the test by means of a Crosby gauge tester, and the results of the calibration were applied to the gauge readings in computing the results of the test; the readings were also corrected for water column, where necessary.

The jacket gauges, the first and second receiver gauges and the vacuum gauges, being those supplied by the contractor and fastened in place on the gauge board or other portion of the engine, were not calibrated, as extreme accuracy in their readings was not essential for purpose of the test; the recorded readings of these gauges have, however, been corrected for water column where necessary.

The thermometers used were not calibrated.

The scales used in measuring the weight of condensed steam were tested by the government inspector of weights and measures both before and after the trial.

The smaller scales on which the condensation from the jackets, reheaters, etc., were found to be accurate within the range of the weights measured; the larger scales on which the condensation from the condenser was weighed were found to average one pound light within the range of weights measured. A correction for this has been made.

Observations.

With the exception of the measurement of the condensed steams, which readings, as mentioned above, were taken every half hour, and the barometer and thermometer readings, the observations were made every ten minutes.

Weather Conditions.

The weather on the afternoon of Thursday, April 8th, was sunny and warm, for the time of year, but during the night it became much colder, and there was some slight fall of snow. Friday was somewhat cold and damp.

Starting the Trial.

The trial began at 2.30 p.m. Thursday, April 8th, and ended at 2.30 p.m. Friday, April 9th, 1909. The watch used in the trial was compared with a chronometer at the beginning and end of the test, and was found to have lost approximately two seconds in the twenty-four hours.

The engine, after having been stopped for the plunger measurement on the previous evening, had been in operation for at least eight hours previous to the commencement of the trial, and was thoroughly warmed up. It ran satisfactorily throughout, with the exception of a slight vibration, caused by some of the cams operating and the valves on the low pressure cylinder not working quite smoothly.

The poppet valves on the intermediate and low pressure cylinders are arranged to be closed by springs or by air pressure; during the test the spring closure was used, the air compressor being used simply to keep air in the air chambers of the pumps.

Towards the end of the test a small leakage of steam from the high pressure cylinder jacket developed owing to a slight failure of the packing; the drip was caught, and from it the total loss due to this leak estimated. The weight was added to the total weight of water measured on the scales.

Observers.

The observers worked in eight-hour shifts, but each shift was present for about ten hours. These men were all skilled in such work, being students in the fourth year of the Faculty of Applied Science and Engineering of Toronto University.

The trial was under the direction of Professor Robert W. Angus, and was carried out by Mr. M. R. Riddell, in conjunction with Mr. W. W. Gray and Mr. J. J. Traill, all of the Faculty of Applied Science of the University of Toronto.

All calculations from the original observation sheets were made by Mr. Riddell. These calculations have been thoroughly checked.

Mr. Hill watched the test in the interest of the contractors.

The engineers and firemen at the pumping station were under the direction and control of the station engineer.

Measurements of the Pumps Used in Computations.

High-pressure Plunger—

Stroke, actual	inches,	35.947
Diameter, actual		21.751
Displacement per revolution	cubic feet	7.730

Intermediate-pressure Plunger

Stroke, actual	inches	36.007
Diameter, actual		21.757
Displacement per revolution	cubic feet	7.747

Low-pressure Plunger—

Stroke, actual	inches	35.972
Diameter, actual		21.760
Displacement per revolution	cubic feet	7.742
Total displacement per revolution	cubic feet	23.219
Total displacement per revolution	imp. gals.	144.699
Volume of imperial gallon	cubic inches	277.274

Observations and Results.

Date of Trial—

2.30 p.m. Thursday, April 8th, to 2.30 p.m. Friday, April 9th.

Duration of Trial—24 hours..

Corrected Average Pressures—

Boiler pressure by gauge, pounds per sq. inch	150.21
At engine pressure by gauge, pounds per sq. inch	148.85
In first receiver by gauge, pounds per sq. inch	24.04
In second receiver by gauge, pounds per sq. inch (below atmosphere)	4.09
In intermediate jacket by gauge, pounds per sq. inch	39.08
In low pressure jacket by gauge, pounds per sq. inch	1.17
Vacuum by gauge, ins. mercury	27.39
Pressure on discharge main, pounds per sq. inch	85.14
Pressure on suction main, pounds per sq. inch	25.16
Height of centre line of discharge main above centre line of suction main at point of gauge attachment feet	0.7
Corresponding pressure, pounds per sq. inch	0.30
Total pressure, difference on pumps, pounds per sq. inch	60.28

Barometer, average, at pump floor level and temperature, ins. mercury	29.54
Average Temperatures—	
Of engine room, degrees Fahr. (lower platform)	76
Of boiler room, degrees Fahr.	66
Of exhaust steam, deg. Fahr.	105.5
Calorimeter—	
Pressure of supply steam at calorimeter, pounds per sq. inch	148.85
Pressure of steam in calorimeter (1 in. mercury =.4908 pounds per sq. inch)	1.21
Temperature in calorimeter, degrees Fahr.	298
Moisture in steam, per cent.	0.72
Speeds—	
Total number of revolutions by counter	43,185
Average revolutions per minute	29.99
Average plunger speed, feet per minute	179.814
Water Pumped—	
Total number of revolutions	43,185
Plunger displacement per revolution, cubic feet	23.219
Plunger displacement per revolution, imp. gals.	144.699
Displacement in twenty-four hours, imp. gals	6,248,813
Work Done—	
Total number of revolutions	43,185
Displacement per revolution, cubic feet	23.219
Total pressure difference on pumps, pounds per sq. inch	60.28
Work done per revolution, ft. pounds	201,542
Work done in twenty-four hours, ft. pounds,	8,703,603,033
Steam Used by Engine—	
Total condensation from condenser, pounds	45,091
Total condensation from jackets, receivers, etc., lbs.	8,072
Total steam used by engine, pounds	53,163
Duty—	
Work done by pump in twenty-four hours, ft. pounds	8,703,603,033
Steam used by engine in twenty-four hours, lbs.	53,163
Duty per thousand pounds of steam used, ft. lbs.	163,715,423
Duty required by specifications, ft lbs.	160,000,000

POWER FACTOR CORRECTION.

L. S. ODELL, '09.

In these days A. C. power systems are becoming so common, and the attendant problems in power factor correction, so well understood, that to those familiar with the subject, any further discussion of power factor correction by the use of the synchronous motor must seem superfluous. However, the general installation of these power systems in Western Ontario has to some extent revived interest in an old subject, as is manifested by the enquiries received by manufacturers of electrical apparatus regarding the synchronous motor, its adaptability to the correction of power factor on systems already installed and the size and design of the motor required. It is in the hope that this discussion may be of some service in answering these enquiries that the same is published.

Whenever power is used from an A.C. line, whether it be through the medium of synchronous or induction motors or by means of a transformer, as is the case for lighting purposes, it is always found that the reading of the wattmeter, showing the power used, is less than the product of volts and amperes on the line. The percentage that the former is of the latter is the power factor. The energy component of the power carried by a line is the volt amperes x power factor. We have also to consider a wattless power component displaced 90 degrees in phase from the energy component, so that $P.F.^2 + W.F.^2 = 1$ where W.F. is the factor, by which we multiply the volt amperes to give the wattless power component. In a power system these wattless power components are not registered on the customer's meter, nor do they directly necessitate any increase in power at the generating station. However, a low power factor on a system means that a current much greater than that required for real power consumption is being carried, necessitating greater line capacity, larger machines, etc., and increasing the losses due to inductance, capacity losses, friction, etc. On a light load these losses may become very large, compared with the load, giving a system of very low efficiency.

Induction motors, when working, cause a lagging current. Transformers also constitute an inductive load, and create a lagging wattless component of power› but when used in connection with a lamp load, the reduction of power factor is not so serious. Now the wattless component of a synchronous motor, under certain conditions, leads the power component, so it is at once evident that synchronous and induction motors might be worked together on a system in such a way as to make the leading and lagging effects neutralize and create a power factor of practically unity.

Induction motors are the more common type in use for general purpose work, so that usually a synchronous motor, when it is put in, is employed to correct a loss power factor due to lagging currents caused by the former type of motors. Suppose this power factor is .8. Experiment shows that as the power factor is corrected more and more nearly to unity, the capacity of the synchronous motor required to make a further change becomes relatively much greater as, for example, if a motor of 100 K.V.A. capacity were required to correct the power factor from .8 to .95, one of 200 K.V.A. capacity would probably be required to bring it up to unity. Hence it is not consistent with economy in first cost to install a motor large enough to completely correct the power factor of a system, as the last few per cent. of correction are dearly paid for in the increased K.V.A. capacity required in the motor. The better practice is to install a motor large enough to bring the power factor to .90 or .95 when the system is fully loaded, while on light loads the capacity of the motor will be sufficient to raise the P.F. still higher, and perhaps completely correct it.

The synchronous motor will do its work as a corrector of the power factor whether coupled to an external mechanical load or not. However, it is advisable to put it on such an external load if possible. Such a load will be represented in the motor by a power component in quadrature with the current used for power factor correction, giving a resultant load not much in excess of the correction load even with a considerable mechanical output. For example, in one case it was found that an external load, equal to 50 per cent. of the correction load could be carried with an increase in the required K.V.A. capacity of the motor of only 12 per cent.

The following example will serve to further illustrate the circumstances under which a synchronous motor may be installed. Suppose induction motors are now carrying a load of 800 K.W., with a power factor of .8. It is desired to determine the capacity of a motor of the former type which will correct the power factor to .95 and carry a load of 200 K.W.

Wattless current due to induction motor load at .8 power factor, $\sqrt{1-.8^2}\times{}^1/_{.8}\times 800=600$ K.V.A.

Total wattless current due to load of 1,000 K.W. at .95 power factor$=\sqrt{1-.95^2}\times{}^1/_{.95}\times 1{,}000=336$ K.V.A.

Hence the synchronous motor must furnish the difference between these two results, the former being the initial lagging component and the latter the lagging component after correction. Combining this difference of 264 K.V.A. with the mechanical load of 200 K.V.A. in quadrature we have:

$\sqrt{264^2+200^2}=332$ K.V.A.=total capacity of the synchronous motor.

Then the power factor at which the synchronous motor will operate as $\frac{200}{332} = .6$ approximately.

Hence in above case a synchronous motor of 332 K.V.A. capacity must be installed, and the excitation so controlled that it will operate under a power factor of .6.

The reason for this adjustment of excitation is as follows: Such a motor when operating under any particular impressed voltage, sustains a constant magnetic flux, no matter what the exciting current may be. A lagging or leading induced armature current is set up, this induced current being such as, when combined with the field excitation, will give a constant magnetizing force. When the fields are over excited a leading current will flow in the armature, and hence a synchronous motor must always be over excited when used to correct a power factor which is held down by lagging currents. When operating a synchronous motor, as explained above an increase in the field excitation will increase the leading current it will draw from the line, while decreasing the field excitation will decrease this leading current until when this leading current falls to zero the motor is operating under unity power factor. A further decrease in excitation would cause the machine to draw a lagging current from the line, so that if necessary a synchronous motor could be used to correct power factors for either leading or lagging currents.

Certain important characteristics effect the suitability of a motor for this class of work. Any AC generator would operate as a synchronous motor, but used for correction of power factors held down by lagging currents, might not be satisfactory. These machines are over excited, and the excitation increases directly as the current, while the heating effects in the field coils increase as the square of the current. Hence machines of low frequency where the number of poles is small and which often give trouble by heating when used as generators, will not do at all, owing to the high temperature in the fields. A machine with a small air gap decreases the amount of excitation necessary. Also the weaker the armature, or in other words, the fewer the coils in it, and the lower the resistance of those coils, the greater will be the induced leading current for the same increase in field excitation. Hence the characteristics of a good machine for power factor correction are a large number of low resistance fields, a small air gap and a weak armature. Such a machine, however, is not likely to be satisfactory as a generator.

Throughout the country there are a great many induction motors operating on power factors of from .5 to .7, and in many cases power consumers are being penalized by the companies, who insist on a power factor of .9 to secure the lowest rates. The synchronous motor offers a means of correction of this difficulty. In many cases, however, the saving will not justify the expense entailed, especially where there is the employment of skilled labor to be reckoned on along with the installation. In other cases, where the load is taken off at only a short distance from the generator, the initial expense is again prohibitive, as the increased generator capacity is the only saving effected. However, on long transmission lines where a low power factor necessitates increased capacity of generators, step up and step down transformers and all other apparatus in the system there is no question as to the advisability of using some means to balance up the lagging and leading currents and hold the power factor as near unity as possible.

THE ENGINEERING SOCIETY

The November sectional meetings of the society were held on Wednesday, the 16th. J. W. Nelson, B.A. Sc., addressed the civil section on "Surveying the Alaska Boundary." His paper was well illustrated by a series of 150 slides, and being well acquainted with his subject, he said a great deal to relieve the impression that the country was an uninteresting one. "Water Wheel Governors," by E. R. Frost, B.A. Sc., was the subject at the mechanical and electrical meeting. The paper appears in full elsewhere in this number of "Applied Science." The miners and chemists were favored with an address on "Common Food Stuffs; Their Manufacture and Adulteration," by L. J. Rogers, B.A. Sc. All the meetings were well attended.

On Wednesday, Nov. 9th, the men of the third year journeyed to the Lackawanna Steel Plant, Buffalo, under the direction of Mr. T. R. Loudon and Mr. J. A. Stiles. In parties of ten and twelve, they were guided through the works, and given an excellent chance of seeing the various processes, from the unloading of the ore at the docks, to the loading of the finished product for shipment. The entire series of processes covers a period of about fifteen hours, and requires the services of some 7,000 men.

Another beneficial excursion, this one under the supervision of Mr. Murphy, vice-president of the civil section, was that to Centre Island, where the new filtration plant is in the course of construction. Mr. Longley, the engineer in charge, spared no pains in guiding and instructing the men as to what is being accomplished there. He not only went into the details of the plant, but also explained many of the outside aqueous problems.

NOTICE.

The graduates in and around Toronto should keep in mind a special meeting of the Engineering Society on Monday evening, Dec. 12th. Mr. Isham Randolph, of Chicago, is to give an illustrated address on the "Ship and Sanitary Canal of Chicago." To hear Mr. Randolph, one of the foremost consulting engineers in America, is an opportunity open to all who can possibly attend.

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EDITORIAL

Enclosed with this number, every reader of "Applied Science" will receive a post card for the attention of the graduates asking for address and particulars regarding employment. This card should be filled in, returned, and placed upon the Secretary's desk for reference. In thus accomplishing his part, the graduate may expect the requested information to be always within easy reach when occasion calls for it. It matters not whether the enquiry be from a fellow graduate renewing acquaintances with old classmates, or from a firm in search of professional assistance, the result will be of advantage to the graduate whose whereabouts is on record at the most convenient centre. There are, on file, records of engineering experience of a large number of men, but, in numerous cases, these are without present addresses, and present employment, and are consequently, not up-to-date. The employment bureau has been successful in placing almost every man who applied to it for employment, and has often been in receipt of more enquiries for men than of applications for work. This points to the fact that the bureau is receiving recognition by engineering firms, as a fit and proper place to apply for technical men, and the younger graduate should not fail to obtain from it the assistance it is intended to convey. His best move is to assure himself that the secretary of the faculty has his name, address and professional experience to date. In short, the closer relations the graduate has with his college the better, from every point of view, no matter whether satisfactorily employed or not.

LEONARD.*

To the Editor of Applied Science:—

Sir:—What is an engineer? Leonard says he is a man who does things.† The man on the street and the newspapers say that an engineer is one who drives engines; more particularly locomotive engines, for the driver of mill engines is a "stationary engineer." The unqualified term belongs to the driver of the locomotive, that quiet, unassuming, but all-important factor in modern transportation, the big man of the train equipment that the public never tips nor sees. Other men are mechanical engineers, civil engineers, mining engineers, and so on, but to the public the mechanical engineer is a man in overalls, greasy-handed and black-marked as to the nose and eyes, who works around machines, the civil engineer is a man with a queer brass instrument on three legs, and the mining engineer is a bad type of crook associated with wild mining flotations. Is it possible that in these days there can be thinking people who have such ideas? It is more than possible, it is an everyday experience. Ask the lawyers who, as a general thing, are our best-posted citizens, and unless they have been on a case where technical witnesses of experience have enlightened them, they will show only hazy, unformed ideas as to the real status or aims of technically trained Engineers. They do not distinguish between them and the mechanic or the plumber. They seldom think of calling them in to be guided by them; they employ them to do certain things for them, to measure or construct, much as they would have a druggist concoct a prescription, and they pay him accordingly. And the engineer does the work and is paid accordingly and says nothing.

The Engineer—the technically trained man—does things, does everything that makes for health and growth and prosperity and lets it go at that. And the world at large sees no more of him and thinks no more about him than does the Pullman passenger and the driver that has brought his train through all the hazards of the trip.

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*R. W. Leonard was appointed to the Board of Governors of the University of Toronto last Spring.

†"The Scope of Engineering in Canada," by R. W. Leonard, "Applied Science," Nov., 1910.

The Engineer is so busy with his work, so interested in his things that he neglects his fellowman. The Churchman, the Doctor, the Lawyer, our professional men, are wiser, they pay more attention to their fellowman than they do to their work, or perhaps it would be truer to say that their eye is first on their fellow. They advise, they guide, they control (perhaps they cajole, flatter or bulldoze), and their fellowman, being but a short time removed from childhood or tribal custom, places them on a pedestal and is glad to be a parishioner, or a patient, or a client. We care nothing for such matters; we want our work, our pride it is to do our work, and all we ask of our fellow is to stand aside and let us do this work. And so it is that we who do the nation's real work amount to but little in the public estimate. We are neither known nor understood. There are in Canada a few, a very few, exceptions that go to prove the rule. Sir Sandford Fleming is an example. How many of the younger generation of engineers take any active interest in their fellows? Very, very few. How many take part in public affairs off the beaten path of their work? There is not one of prominence, unless it be Leonard. He is a peculiarly all-round man. He began with the military training of the R.M.C. In his early work he made a marked success in railroad construction, and later in water power development. He was always interested and generally dabbling in mining. Cobalt was his opportunity and he took it. His Coniagas success was much more the work of the experienced calculating financier than the luck of the explorer. He has always been keen in military affairs. The Leonard Gig is an accepted part of field equipment. And now he is an assured financial success. He has money. That must be writ large, for despite all we may say or pretend to think to the contrary, money counts in these days. And be it noted he made his money as an engineer, cleanly. And still he remains an engineer, taking a keener interest in his engineering work than in anything else. And on top of all this he is stepping out to take a part in his fellows' affairs; to take an active, disinterested part in the larger affairs of the nation. As a graduate of the school I am particularly glad that his first energies are with Toronto University. The School needs him. We all recognize the advantages of a special pleader, and the School is no doubt in need of a counter-balance to the urgent calls upon the funds from Arts and Medicine and the apparently innumerable new faculties. But personally I should be sorry to see Leonard either become or be looked upon as a special pleader for the material growth of the School. His is a larger function. It is a safe bet that the Engineer and his aims are as little understood in the University councils outside of the Faculty of Engineering as they are by the public. It is up to Leonard to tackle the larger education, the education of those in control.

Yours etc.,

AN OLD GRADUATE.

HARRY MILL LANCASTER.

Since the last issue of "Applied Science" we learn with great regret of the resignation from the staff of Applied Chemistry of Mr. H. M. Lancaster. Mr. Lancaster's academic career has been marked with singular ability; coming from Woodstock Collegiate Institute with a first Edward Blake scholarship in Science and a second in Science and Mathematics, he entered the Arts Honor courses of Physics and Chemistry and Chemistry and Mineralogy, with the class of '05. In both these courses he carried off the scholarships in his freshman year. Full first-class honor standing in his first three years enabled him to transfer to the fourth year in the Department of Applied Chemistry, where he selected the Sanitary and Forensic option. Since his graduation in 1906 with the degree of B.A. Sc., with honors, Mr. Lancaster has been connected continuously with the Department of Applied Chemistry, first as fellow, and from 1907 till the time of his resignation, as demonstrator. In addition to his academic work, he pursued many outside interests, always, however, directing his special attention to toxicological investigations and food and water analysis. This particular line of work, in which he had the good fortune of personal association with Dr. Ellis, fitted him ideally to assume the duties his present position entail. His co-workers on the staff and his students unite in wishing him every success in the responsible post to which he has been appointed.

BOOK REVIEWS

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS.

(McGraw-Hill Book Co., Third Edition; Leather).

One of the outstanding needs of every student of electrical matters is a handbook which embodies in convenient form a large collection of useful data accompanied by sufficient explanation and general information to enable him to properly use the data. Such a companion is the "Standard Handbook."

The men who have compiled the various sections of the book are engineers of standing, who have made critical study of the subject in hand. It is natural, therefore, to find that necessary explanations involving complexity and formulae are not avoided in the Standard as in some other handbooks. This feature is of value to students whose point of view demands understanding of means and methods rather than accumulation of data and results alone.

Sections 1, 2, 3 include in concentrated form information on units, methods and calculations which appeals to students because it bears directly on one large phase of their studies. Section 4, on properties of materials, supplements the previous sections by providing considerable definite data for use therewith.

Sections 5 to 9 refer to the theory, design, construction, operating properties and testing of generators, motors, transformers, batteries, magnets, rheostats, etc. There is presented a surprisingly large quantity and variety of information. The treatment is very complete, considering the space available.

Sections 10 to 18 deal with the problems of electricity as applied to central station plants of all kinds, transmission and distribution, under various conditions, electric lighting in general, electric traction in its many phases, from 600 volt city services to 11,000 volt heavy traction problems, electro-chemical problems, with their industrial applications and practice, telephony, telegraphy, etc., etc. Each section is an excellent text and handbook on theory and practice in its field.

Section 19 is useful, as it covers the standardization rules and recommendations of the best engineering associations in America. Section 20 includes a number of mathematical tables and statistical data relative to electrical industries.

When in search of information the reader is assisted in locating matter in point by the use of heavy type in the text for words in each paragraph, which suggest the subject matter thereof. The index seems complete, but would be much more effective if cross-indexing were considerably increased.

The "Standard Handbook" will be a permanently valuable addition to the library of any student. *Reviewed by H. W. Price, B.A. Sc., Dept. of Electrical Engineering.*

WHAT OUR GRADUATES ARE DOING.

W. H. Munro, '04, has been appointed manager of the allied companies: the Peterboro' Light and Power Co., the Peterboro' Radial Railway, and the Auburn Power Co., of Peterboro', after having been engaged for the past six years in hydro-electric work.

H. F. H. Hertzberg, '07, is with the Trussed Concrete Steel Co., of Canada, in their Winnipeg office.

W. M. Bristol, '05, is on the staff of the Canadian Westinghouse Co., in their Halifax branch.

Fred H. Moody, '08, has been appointed associate editor of "Machinery," published by the Industrial Press, New York.

P. T. Kirwan, '10, and A. V. Delaporte, '10, have been appointed Fellows in Chemistry for the session 1910-11.

L. J. Rogers, '07, who has for some time been chemist for the Pure Gold Manufacturing Co., succeeds Mr. Lancaster as demonstrator in Chemistry.

Willis Maclachlan, '06, previously construction engineer in Hydro-electric work, Niagara, has been appointed city engineer for London, Ontario.

G. R. Workman, '10, lately of the Canadian Bridge Co., has accepted a position with the Laurentide Paper Co., Limited, of Grand Mère, Quebec.

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